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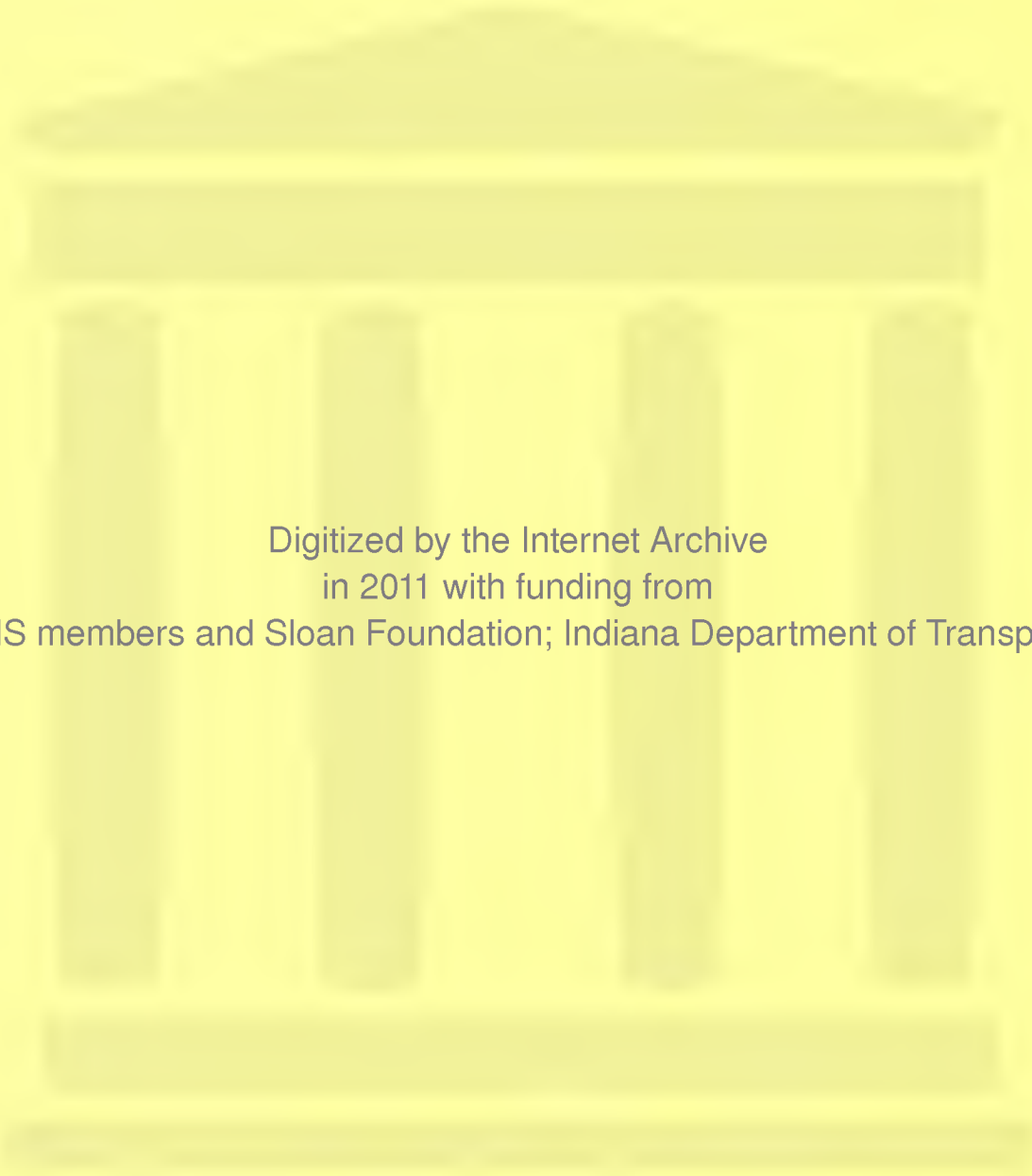
JHRP-78-12

APPLICATION AND FIELD  
EVALUATION OF VERY THIN SKID  
RESISTANT PAVEMENT SURFACES

Ryan R. Forrestel



PURDUE UNIVERSITY  
INDIANA STATE HIGHWAY COMMISSION



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16. Abstract <p>The objective of this study was to improve skid resistance on worn, structurally sound, portland cement concrete pavements. This was accomplished through the evaluation of predetermined mixes and application techniques in the field through the application of very thin, concrete overlays. The overlays 3/8 inch or less in depth, were applied by two distinct application techniques, brooming and screeding. The four predetermined mixes were applied in twelve overlays.</p> <p>The goals of the field work were: 1) evaluation of the application techniques; 2) evaluation of the predetermined mixes; 3) evaluation of adhesion. The evaluation of the mixes with respect to performance over time and adhesion will be monitored for a period of one year. At that time the most promising overlays will then be considered for further testing on a larger scale.</p> <p>This Report covers the field work installation of the overlays. In the Fall of 1977, some application of overlays was conducted for experience and adhesion testing purposes. In the Spring of 1978, twelve strips each 3 feet wide by 150 feet long, were placed. The first four were screeding and rest were brooming. Two admixtures, latex and acrylic, were used to improve adhesion between the overlay and pavement. Both proved to be initially effective.</p> <p>The overlay skid resistance was evaluated by the use of a skid trailer. Initially, broomed overlays using the lightweight aggregate gave the highest skid resistance with the screeded overlays providing the least skid resistance.</p>			
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Interim Report

APPLICATION AND FIELD EVALUATION OF VERY THIN SKID  
RESISTANT PAVEMENT SURFACES

TO: Harold L. Michael, Director  
Joint Highway Research Project

FROM: C. F. Scholer, Research Associate  
Joint Highway Research Project

August 2, 1978

Project: C-36-53L

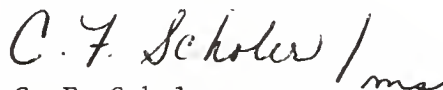
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The attached Interim Report is submitted on the HPR Part II Study titled "Thin Applied Surfacing for Improving Skid Resistance of Concrete Pavements". This Report is titled "Application and Field Evaluation of Very Thin Skid Resistant Pavement Surfaces". This is the second Interim Report on this Study.

The Report has been authored by Ryan R. Forrestel, Graduate Instructor in Research, who was in charge of the field work under the direction of Professor C. F. Scholer. Evaluation of the overlays as to durability, skid resistance and other characteristics will continue for at least the next year.

The Report is presented for review and comment and acceptance as partial fulfillment of the objectives of the Study. Following presentation to the JHRP Board on August 2, 1978, it will be forwarded for similar acceptance by ISHC and FHWA.

Respectfully submitted,



C. F. Scholer  
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Interim Report

APPLICATION AND FIELD EVALUATION OF VERY THIN SKID  
RESISTANT PAVEMENT SURFACES

by

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Project No.: C-36-53L

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Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project  
Engineering Experiment Station  
Purdue University

in cooperation with the

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and the

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The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Purdue University  
West Lafayette, Indiana  
August 2, 1978

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## HIGHLIGHT SUMMARY

The objective of this study was to improve skid resistance on worn, structurally sound, portland cement concrete pavements. This was accomplished through the evaluation of predetermined mixes and application techniques in the field through the application of very thin, concrete overlays. The overlays, 3/8 inch or less in depth, were applied by two distinct application techniques, brooming and screeding. The four predetermined mixes were applied in twelve overlays.

The goals of the field work were: 1) evaluation of the application techniques; 2) evaluation of the predetermined mixes; 3) evaluation of adhesion. The evaluation of the mixes with respect to performance over time and adhesion will be monitored for a period of one year. At that time the most promising overlays will then be considered for further testing on a larger scale.

The field work was divided into two parts. Part One was conducted in Fall 1977. This work had no bearing on the project other than to gain experience using the application techniques and to allow the applied strips to go through the freeze-thaw cycles of winter. The two overlays applied failed in adhesion very soon after their completion. Upon completion of Part One several changes were made in Part Two.

Part Two was conducted in Spring 1978. Twelve strips, each 3 feet wide by 150 feet long, were placed. The first four were screeding and the rest were brooming. Two admixtures, latex and acrylic, were used to improve adhesion between the overlay and pavement. Both proved to be initially effective.

The overlay skid resistance was evaluated by the use of a skid trailer. Initially, broomed overlays using the lightweight aggregate gave the highest skid resistance with the screeded overlays providing the worst skid resistance.

The author provided possible adaptations to the application techniques in order to expand them to a larger scale for practical field use.

## CHAPTER 1: INTRODUCTION

In recent years much attention has been directed toward means of decreasing the number of accidents by improving skid resistance. Although the number of motor vehicle accidents has decreased in the United States during the past two years, an unpleasant 1975 statistic shows that motor vehicle accidents in that year cost \$21.2 billion and resulted in 1,800,000 disabling injuries and 46,000 deaths (1). Wet-weather traffic accidents are estimated to be accountable for about 15% of motor vehicle accidents resulting in injury or death (2). It has been suggested that at certain high accident sites, the wet-weather accident rate may be 10 to 20 times the dry-pavement rate (3). The new concrete pavements of the 1960's and early 1970's are quickly becoming the smooth, potentially dangerous pavements of today. This, coupled with higher accident costs and the liability of State Highway departments to provide safe roads, has intensified efforts to develop skid resistant pavements. Responding to this call, engineers have developed many schemes to improve skid resistance on concrete pavements, mostly dealing with surface texturing or the use of overlays 1 inch or more in depth. Very little, if any, attention has been directed toward the use of very thin, portland cement concrete overlays.

### Purpose of this Research

The primary purpose of this research was to evaluate application techniques for applying very thin, concrete overlays to old, worn, concrete pavements. In the context of this research, a very thin overlay is defined as being approximately 3/8 inch in depth or less. Particular emphasis was given to the feasibility of practical field use of the application techniques. It was anticipated that with the procedures for overlay application, and given the proper equipment, one or more of the techniques could be used economically and efficiently to improve skid resistance in small, local areas or large, sectional areas. Overlay bonding, achievement of rapid set in the overlay and achievement of initially high skid numbers also were considered.

The procedure receiving the most emphasis was shotcrete. Shotcrete has been used in the United States for many years (4). It is used frequently for various types of concrete repair work and as a protective coating over surfaces which would be subjected to disintegration or corrosion without such protection.

Under proper workmanship, shotcrete can provide a concrete with low water permeability, high strength, and may be used with accelerators giving very rapid strength gain.

Since shotcrete causes the material to be forced against the receiving layer with considerable force, it was anticipated that a good bond could be achieved by forcing material into surface irregularities of hardened concrete. And with the use of rapid accelerators to give strength rapidly to the overlay the potential of

the concrete overlay as a maintenance method on heavily travelled highways would be greatly improved.

Because of the scope of the research and because of various constraints, the method of pavement surface cleaning and its interaction with the adhesion of the overlay and the effect of traffic on wearing of the overlay were not included in the research. The mix design and evaluation of the aggregates for the various overlay mixes was done by Mr. Jorge Gomez (5) and previously reported in a Joint Highway Research Project interim report.

#### Organization

The field program was conducted in two major steps. The first part was done in the Fall of 1977. It consisted of using the application techniques in order to become familiar with them and to work out any "bugs" that occurred. The effect of the freeze-thaw cycles on the overlays was also of interest.

The second part was the main body of the research program. It utilized the experience gained in the fall to modify the application techniques into more efficient operations. The major portion of the field work consisted of using the application techniques to apply the various mixes. After the field work was done and skid numbers were taken, evaluation of the mixes and application procedures, and their results, were analyzed and evaluated. The field performance of the overlays will continue to be monitored as part of the research project.



## Background and Significance of Work

In the area of improving skid resistance with thin concrete overlays most of the work in recent years has been directed toward the use of bonded overlays approximately 1-1/2 inches or more in depth. Rigorous procedures have been used to insure a good bond, these included sandblasting; spreading grout immediately ahead of overlaying; removal of deteriorated joints; and grinding of the surface. The overlay can be applied by slip form paving (6).

The use of very-thin overlays has been restricted mainly to upgrading bridge decks, but again these were usually 1-1/2 inches or more in depth. Some work has been done to improve skid resistance with the use of an epoxy paint in local areas such as dangerous curves.

After a thorough literature review no information was found with regards to the use of very thin concrete overlays to improve skid resistance. It is felt that this was the first research project dealing in this area.

## CHAPTER 2: DESIGN AND PLANNING OF FIELD WORK

Prior to the planning of the field work to be done, the goals of the research were defined. These were essentially to compare various application procedures for applying very thin, concrete overlays. After the goals were defined the design of the field work could begin. It was decided that an effective way to evaluate the application procedures and mixes was through the use of strips laid on a concrete pavement. The strips were to be of adequate length and width to permit the use of the skid trailer in accordance to ASTM E 274. The skid testing would be done by the Research and Training Center of the Indiana State Highway Commission. The site for the research was then selected and the field work planned. Since the researcher had limited knowledge and experience with the application techniques, the work was divided into two parts as was stated in Chapter 1.

### Goals

Because of the narrow scope of this research, the goals were accordingly set. There were three primary goals of the field work: 1) evaluation of the application techniques; 2) evaluation of the pre-determined mixes; 3) evaluation of adhesion.

The application techniques initially planned on being used were screeding, brooming and shotcrete. The shotcrete process was briefly evaluated in Part One with valuable experience being gained.

However, due to problems beyond our control it was not possible to use the shotcrete method in Part Two. Therefore, only the brooming and screeding procedures were used in Part Two.

Each application technique was used to apply a given mix. This allowed a comparison to be conducted between the techniques to study the effects of an individual technique on the mix and its placement. From the outset it was anticipated that as the type of technique was varied the performance of the mix would also change. This was clearly demonstrated with actual field use as discussed in Chapter 4.

On the other hand with a given technique and the four mixes used with the technique, the effect of the mix and its components or the technique could be closely studied. The components of the mix anticipated to cause the most variability was the water and cement content of the mix; as the cement content and water content were increased, the ease of application also increased.

The third goal, evaluation of adhesion, was severely restricted by the research purpose. The purpose was to evaluate adhesion of the overlay to the original pavement without any alteration to the surfacing, i.e. sandblasting, chipping or grinding. The only surface preparation done was cleaning. Since the pavement of the site was without oil or rubber stains, it was determined cleaning was insignificant in this research. This was thought acceptable because the effectiveness of the various cleaning methods have already been thoroughly proven for dirty pavements (7).

A secondary goal of the research was to organize and perform the field work in a systematic manner so that detailed records of time, materials used and manpower could be kept. With these records a comparison of each application technique relative to each other could be made. The most efficient method was then compared with other overlay methods done on a large scale. (See Chapter 6).

### Strip Design

The strips had to be of adequate dimensions to permit the use of the skid trailer to test skid resistance. It was initially determined that a strip, 3 feet wide and 300 feet long, was optimal with respect to the operation of the skid trailer (8). However, during Part One, it quickly became apparent that the length was prohibitive for the intended purpose and time allotment. After further discussion with the Indiana State Highway Commission the length was reduced to 150 feet while the width remained 3 feet (9).

### Site Selection Criteria

In finding a site for the field work five criterion had to be met in order for the pavement to be acceptable:

1. Low volume road.
2. Closeable to traffic with little inconvenience to motorist.
3. Worn, structurally sound, concrete pavement.
4. Close proximity to Purdue University.
5. Of sufficient length to allow proper skid testing.

The reason for requiring a low volume road was one of safety. By minimizing the traffic volumes the chance of having an accident or mishaps in the event the overlay did not bond properly, would be reduced. Secondly, with minimal volumes the number of motorists disrupted by closing the road would also be reduced.

In order to minimize the inconvenience to motorist by closing the road alternative routes must be available that are as short and direct as possible.

Since the overlay is not intended to add structural strength to the pavement, the test pavement must be structurally sound. However, it would be advantageous for the pavement to be cracked, joints faulted or deteriorated, and its surface pitted with popouts. This would make the bonding of the overlay even more difficult and more realistic.

The site must be close to Purdue for the obvious reasons of economy and efficiency. The site also had to be of sufficient length to allow skid test of 60 mph to be run and allow adequate stopping distance. Also of concern was the possibility of this speed being a hazard to any residents living in the immediate area.

#### Site Description

After meeting with members of the Indiana State Highway Commission (10) several sites were recommended. After visiting each site only one was found to meet all of the criteria necessary. The site chosen was County Road 500N in the very western portion of Tippecanoe County (Figure 1). The road leads from Otterbein to U.S. 52,

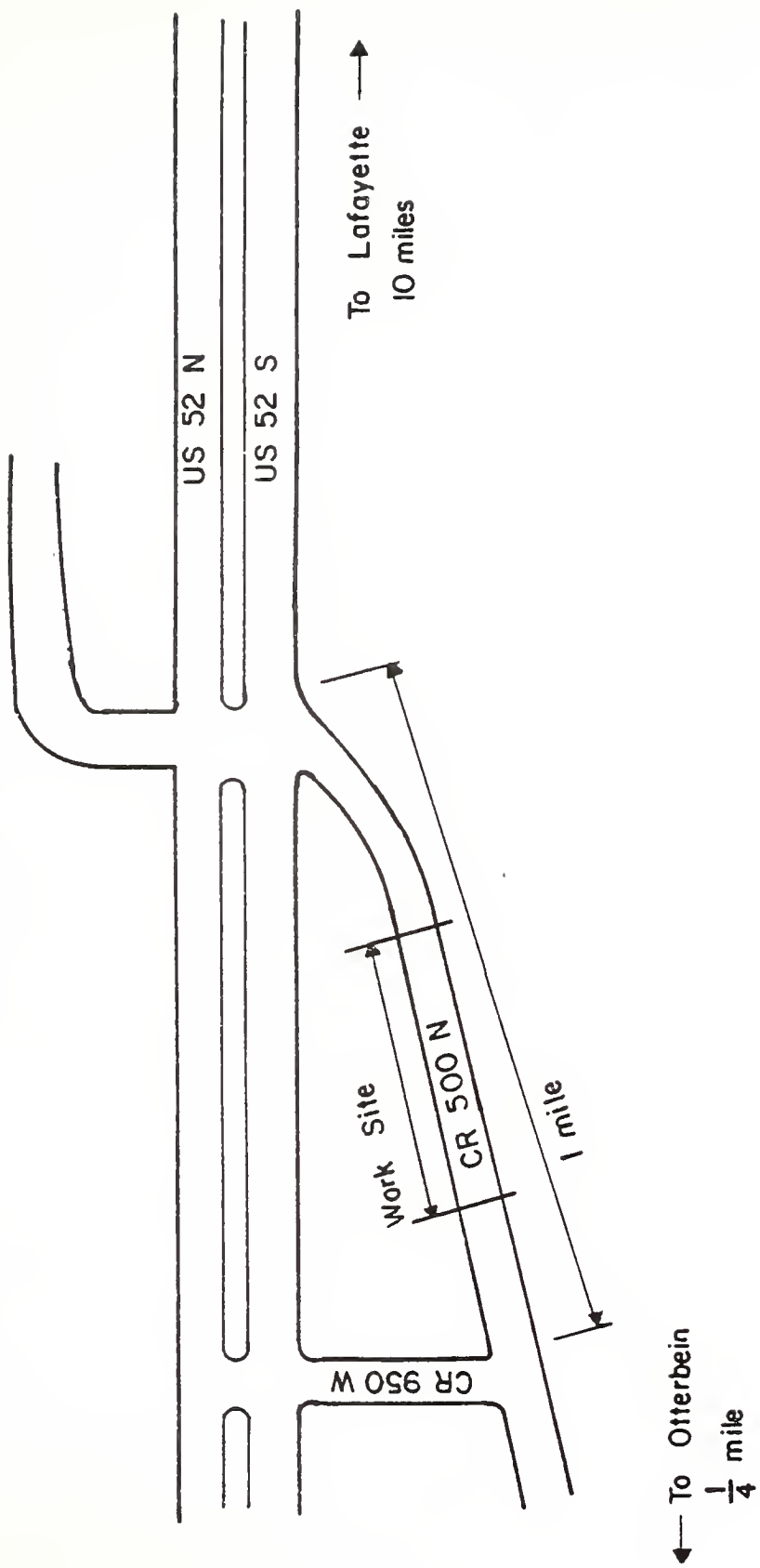


Figure 1. Location of Job Site

approximately 1.5 miles long. The site is about 11 miles west of Purdue University.

The pavement was 18 feet wide with joints every 60 feet (see Figure 2). Some of the joints were badly deteriorated with bituminous patches and others were faulted with bituminous patches. A typically patched joint is shown in Figure 3. The pavement was badly pitted and had many cracks, but was very clean with no oil or dirt stains visible.

#### Field Work: Part One

As stated earlier the field work was divided into two parts. Part One dealt with the work done in Fall 1977 and Part Two with the work done in Spring 1978. This section deals with a brief review of the Part One field work and any changes introduced in Part Two because of it. The field work of Part Two, the main body of the research, is discussed in the following section.

Part One had two major components, the first was the experimental work done at the Indiana State Highway Commission's Research and Training Center in West Lafayette, Indiana. Several small test pads were laid to initially evaluate the mixes and the application techniques. Of principle concern was the effect of the water content on the mix, the sand-cement ratio, type of forming to be used on the side of the strips, and applicator used in the screeding and brooming techniques.

After applying mixes with varying water contents, the optimal water-cement ratio was estimated to be .40 to .50.\* Lower than .40

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\*Water cement ratio based on weight.





Figure 2. County Road 500 North



Figure 3. Typically Patched Joint

the mixes were too harsh to work and greater than .50, the mixes became too wet and were subject to severe shrinkage cracking. The mixes consisted of a sand-cement ratio of 2:1 to 3:1. The optimal sand-cement ratio appeared to be between 2.5:1 and 2.75:1.

Two types of forming were tried. The first was 3/8 inch x 8 inches wide plywood, but this proved to be very poor. During screeding the concrete would spill onto the plywood causing the screed to rise up over it. Then 3/8 inch x 1-1/2 inches door stop was used. This was very effective, as the aluminum channel was moved laterally across the strip, the excess concrete would roll over the door stop and out of the way.

Several applicators were tried for the screeding operation. The most efficient and effective applicator was an aluminum channel, 5 inches wide by 1-1/2 inches deep. Of the different bristle coarsenesses tried, a broom with fine bristles was found to be the most effective for use in the brooming technique.

With these initial findings the second component of Part One could begin. The actual field work consisted of applying several strips 3 feet x 300 feet to the test site pavement in order to evaluate the application techniques and the overlay bonding through the freeze-thaw cycles of winter. It was not intended for these strips of Part One to be part of the data for evaluation of the mixes, techniques or bonding. Therefore they had no bearing on the outcome of the project other than being useful to gain experience for the Spring work. Two 300 foot strips were laid in Part One. The first was applied by the screeding method and the second by brooming. The

aggregate used in both mixes was Indiana #13-2 sand. The sand-cement ratio for the screeding and brooming mixes were 2.75 and 2.50 respectively. The final overlay texturing was achieved by dragging a coarse broom laterally across both strips (Figure 4).

After Part One was completed the following changes were made in the application techniques:

1. The length of each strip was reduced to 150 feet from 300 feet.
2. The thickness of the broomed strips was reduced to 1/16 inch.
3. Surface texturing by brooming was replaced with tining.

The length of each strip was reduced to 150 feet because of the time required to apply 300 feet of overlay to the pavement. The screeding method required almost two working days while the brooming required approximately 1.25 days to apply a strip 3/8 inch in depth. A strip length of 150 feet was also more effective with respect to skid trailer operation. At 60 mph only two passes were required to achieve 100 percent coverage while at 50 mph and 40 mph three passes gave 100 percent coverage. With 300 foot strips speeds of 60, 50 and 40 gave cover of 88.0, 73.3 and 58.7 percent, respectively, with three passes at each speed.

The brooming technique of overlay application was found to be very ineffective when applying an overlay of 3/8 inch. With this technique, the depth of the overlay was very difficult to control, a very undulating surface resulted in a rough riding pavement (Figure 5). By reducing the depth to approximately 1/16 inch and by using a



Figure 4. Brooming Final Texture



Figure 5. Brooming 3/8 Inch Overlays

slurry-like mix, the overlay could be applied with a uniform thickness. This was thought to be a more feasible procedure in actual field use than using an overlay of 3/8 inch thickness.

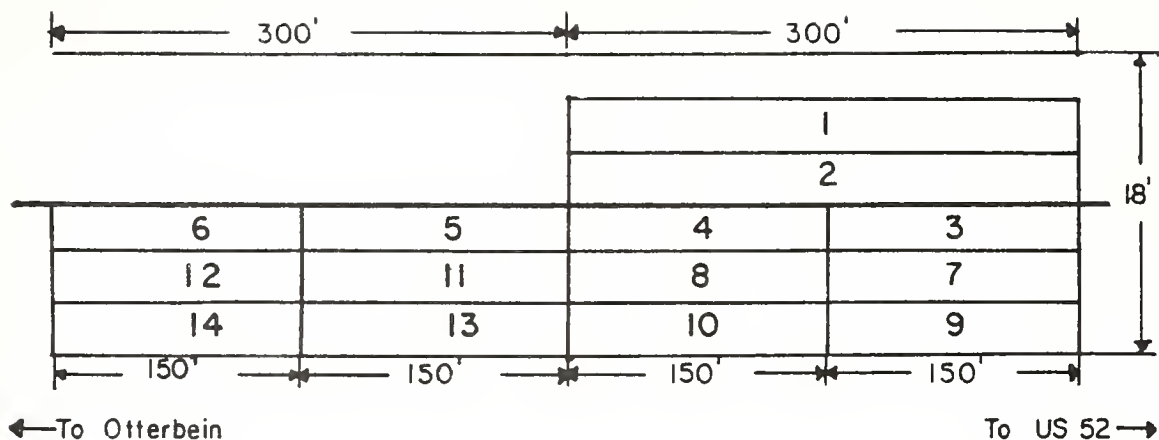
The surface texturing method was changed to tining because brooming is no longer used in the State of Indiana. It should be noted here that no surface texturing was planned for overlays applied by the shotcrete technique. This is because the surface texture is naturally gritty and thought to provide a good, durable, skid resistant pavement.

#### Field Work: Part Two

In Part Two four mixes were applied using two application techniques, screeding and brooming resulting in twelve overlays. (The mixes are given in Chapter 3 and the application techniques are discussed in Chapter 4). The work took approximately three weeks to complete. The layout of the twelve strips is shown in Figure 6a. Figure 6b lists each strip shown in Figure 6a and gives which part of the project it was applied in, the application technique, overlay depth and its mix number.

Each mix varied in the aggregate type, sand-cement ratio, amount of latex added and in the use of an accelerator. The aggregates used were lightweight aggregate (expanded shale) and slag. The sand-cement ratio varied from 2.0 to 2.75 for the slag and 1.0 to 2.0 for the lightweight aggregate. Dow Chemical Latex 464 and Rohm and Haas Rhople MC-76 were used to improve strength and bonding characteristics. The accelerator when used was calcium chloride ( $\text{CaCl}_2$ ). Further details of the mixes are provided in Chapter 3.

(a)



(b)

<u>Strip No.</u>	<u>Part No.</u>	<u>Application Technique</u>	<u>Overlay Depth Inches</u>	<u>Mix No.</u>
1	One	Screeding	3/8	1
2	One	Brooming	3/8	2
3	Two	Screeding	3/8	3
4	Two	Screeding	3/8	4
5	Two	Screeding	3/8	5
6	Two	Screeding	3/8	6
7	Two	Brooming	1/16-1/8	7
8	Two	Brooming	1/16-1/8	8
9	Two	Brooming	1/16-1/8	9
10	Two	Brooming	1/16-1/8	10
11	Two	Brooming	1/16-1/8	11
12	Two	Brooming	1/16-1/8	12
13	Two	Brooming	1/16-1/8	13
14	Two	Brooming	1/16-1/8	14

Figure 6. Layout of Overlays

The application techniques are described in detail and evaluated in Chapter 4. In Chapter 5 the overlays are evaluated with respect to the mixes, their placement, adhesion and skid resistance.



## CHAPTER 3: MATERIALS AND MIX DESIGN

The mix designs for this research came as a result of the work done by Jorge Gomez (11). Gomez's work dealt with laboratory evaluation of various aggregates, admixtures and mix properties with respect to strength, durability and skid resistance. One of his end results was the identification of four distinct mix designs to be further evaluated in the field.

The four mixes are given in Table 1. Also included in the Table are the two mixes used in Part One. Note that for each aggregate only the sand-cement ratio changes.

Table 1. Part One and Part Two Mix Design

Mix	Aggregate <sup>1</sup>	m <sup>2</sup>	w/c	Latex <sup>3</sup>
1	Natural Sand	2.75	.45	None
2	Natural Sand	2.50	.45	None
3	Slag	2.5	.45	40%
4	Slag	2.75	.45	40%
5	Lightweight	1.5	.45	45%
6	Lightweight	2.0	.45	45%

<sup>1</sup>The natural sand was used in Part One, the slag and lightweight were used in Part Two.

<sup>2</sup>m = sand-cement ratio by weight. For the brooming method, m was decreased by 0.5.

<sup>3</sup>Latex liquid by weight of cement.

The water-cement ratio was not taken into account in this project because of the difficulty in accurately measuring the moisture content of the aggregate for each batch. A second more important reason was because of the extreme difficulty in accounting for the variability in the moisture content within the aggregate stockpile. Therefore a w/c of .45 was a target used in making each batch of concrete to be applied.

### Aggregate

The natural sand was a local glacial-alluvial sand. Its gradation is given in Table 2. The fineness modulus was 2.65.

Table 2. Sieve Analysis of Natural Sand

Sieve Number	Percent Retained	Cumulative Percent Retained
4	0.1	0.1
8	9.9	10.0
16	17.5	27.5
30	23.5	51.0
50	32.0	83.0
100	10.0	93.0

Additional properties of the natural sand were: bulk specific gravity (SSD) - 2.52, and absorption - 2.50%, both in accordance with ASTM Designation: C 218-68. The dry rodded unit weight was 110 lb/ft<sup>3</sup>, according with ASTM Designation: C 29-71. The total insoluble residue was 63% in accordance with ASTM D 3042-72 (12).

The lightweight aggregate was an expanded shale from Brooklyn, Indiana. The gradation of the lightweight aggregate is shown in Table 3. Its fineness modulus was 3.2.

Table 3. Sieve Analysis of the Lightweight Aggregate

Sieve Number	Percent Retained	Cumulative Percent Retained
4	.5	.5
8	22.1	22.6
16	29.5	52.1
30	17.9	70.0
50	12.6	82.6
100	7.9	90.5

Additional properties were determined as: dry rodded unit weight - 58.7 lb/ft<sup>3</sup>, bulk specific gravity (SSD) - 1.77, total insoluble residue - 90% and absorption - 15%. All properties were found according to their respective ASTM Specification.

Further information pertaining to the mineral composition of the lightweight aggregate and its description is given in Reference 12.

The slag was a blast furnace slag from Portage, Indiana. Its gradation is given in Table 4 and its fineness modulus was 3.4.

Table 4. Sieve Analysis of the Slag

Sieve Number	Percent Retained	Cumulative Percent Retained
8	0.7	0.7
8	21.5	22.2
16	29.8	52.0
30	26.4	78.4
50	10.2	88.6
100	6.9	95.5

Additional properties were determined as: dry rodded unit weight - 104.4 lb/ft<sup>3</sup>, bulk specific gravity (SSD) - 2.6, total insoluble residue - 75% and absorption - 4%. Again, all properties were found according to their respective ASTM Specification.

Further information concerning a brief description of the slag and its mineral composition is given in Reference 12.

### Cement

Type I portland cement was used throughout the project. All cement came from a single source.

### Admixtures

Three admixtures were used in Part Two, two in an attempt to improve bond and strength characteristics in concrete and the third an accelerator. The former were Dow latex 464 and Rohm and Haas acrylic Rhoplex MC-76. Both admixtures are defined as polymer modifiers of portland cement concretes. Their makeup is essentially polymers dispersed in water having the appearance of a milky liquid.

"Latex 464" was developed by Dow Chemical Company and supplied by Dow Chemical of Midland, Michigan. Table 5 shows typical properties of the Dow latex 464.

The "Rhoplex MC-76" an acrylic polymer, is produced by Rohm and Haas Company of Philadelphia, Pennsylvania. Some of its properties are given in Table 6.

Table 5. Typical Properties of Latex 464\*

Property	Latex 464
Polymer Type	Saran
Stabilizer	Non-ionic
Percent solids	50%
Specific gravity (25°C)	1.23
Weight per gallon (lbs @ 25°C)	10.25
Ph	2.0
Particle size range (angstroms)	1400
Surface tension at 25°C (dynes/cm <sup>2</sup> )	33
Freeze-thaw stability	none (alone)
Specific gravity of latex solids	1.60
Film forming	
25°C	Yes
4°C	No
Shelf time	6 months

\*Supplied by Dow Chemical Company

Table 6. Properties of Rhoplex MC-76\*

Property	Rhoplex MC-76
Solids content	46 to 48%
Ph	9.5 to 10.0
Specific gravity	1.059
Weight per gallon (lbs.)	8.8
Freeze-thaw stability	5 cycles
Minimum film formation temperature	10 to 12°C

\*Supplied by Rohm and Haas Company

The purpose of adding the "Rhoplex MC-76" and the "Dow Latex 464" was to increase physical strength and chemical resistance properties of cement mortars. Both result in a fast forming surface skin when applied in thin sections. An antifoam agent is required in the use of both admixtures. In the case of the latex, Down Antifoam Agent B was used. With the acrylic, GE Antifoamer #60 is recommended. However, because this antifoam agent was not available the Dow antifoam agent was used. This agent was sufficient to defoam the "Rhoplex MC-76" in the laboratory. But when used in the field large numbers of tiny bubbles were visible throughout the mix.

Calcium chloride ( $\text{CaCl}_2$ ), flake form in a water solution, was used as the accelerator.

Initially, the amount of accelerator was added 2% by weight of cement. However, this proved to be insufficient so 3% was used and proved effective.

Since neither Dow Chemical Company or Rohm and Haas Company had done significant amounts of research dealing with the effect of  $\text{CaCl}_2$  on their respective products it was unknown if there would be any adverse effects in using the  $\text{CaCl}_2$ . Therefore the accelerator was added only in the afternoon hours so that the morning and afternoon portions of a strip could be compared. Through this comparison any adverse effects might be detected.

#### Mix Designs

The basic mix designs are given in Table 1. From these basic designs, a mix design was made for each strip applied to the concrete

pavement. The strip mix designs were figured for approximately 1.75 cu. ft. batches as this was determined as an optimal amount to work with. These proportions are given in Table 7.

Several points should be elucidated about the batch mix proportions at this point. First, when calculating the aggregate weight per batch the amounts of water absorbed by the aggregate is included in the weight of aggregate per batch. However, the moisture content of the aggregate (i.e. the amount of free water around the aggregate that is not actually absorbed into the aggregate particles) is not included in this weight. This excess water in the batch is accounted for by estimating the aggregate moisture content and then adding that much more aggregate into the batch. The estimation of moisture content is discussed later. For example, if 150 lbs of slag were added to each batch and the slag moisture content was 10%, an extra 15 lbs of slag would be added.

Second, "Latex 464" is 50% solids. Therefore half the weight of latex added is water and that water must be subtracted from the total amount to be added.

Third, because of the high moisture contents of the aggregates never was the full amount of water added to a batch. As stated earlier the water-cement ratio was not a strict control but a guideline. This was due to the great variability that occurred in the aggregate moisture content not only as the aggregate pile dried, but because of the lack of uniformity in drying within the pile. Therefore, it was extremely difficult to accurately estimate the moisture content for each batch thereby making it nearly impossible to obtain the same



Table 7. Strip Mix Designs

Strip	Aggregate	Absorption	m <sup>a</sup>	Desired w/c	Cement (lbs)	Aggregate <sup>b</sup> (lbs)	Latex <sup>c</sup> (%)	Latex (lbs)	Antifoam <sup>d</sup> B
1	sand	2.50%	2.75	.45	58.75	175.12	None	None	None
2	sand	2.5%	2.50	.45	58.75	160.12	None	None	None
3	slag	4%	2.5	.45	58.75	152.75	40	23.50	.43
4	slag	4%	2.75	.45	58.75	168.00	40	23.50	.43
5	lightweight	15%	1.5	.45	58.75	101.34	45	26.44	.48
6	lightweight	15%	2.0	.45	58.75	135.13	45	26.44	.48
7	lightweight	15%	1.0	.45	58.75	67.56	45	26.44	.48
8	lightweight	15%	1.5	.45	58.75	96.94	45	26.44	.48
9	slag	4%	2.25	.45	58.75	137.48	40	23.50	.43
10	slag	4%	2.0	.45	58.75	122.20	None	None	None
11	slag	4%	2.5	.45	58.75	152.75	40	23.50	.43
12	slag	4%	2.0	.45	58.75	122.20	45	26.44	.48
13	slag	4%	2.5	.45	58.75	152.75	40	23.50	.43
14	lightweight	15%	1.5	.45	58.75	96.94	None	None	None

a. m = sand-cement ratio, by weight

b. Aggregate weight = [(weight of cement x m) + (weight of cement x m x absorption)]

c. Liquid Latex, by weight of cement

d. Antifoam B is 1.82% of latex, by weight

Table 7. Continued

Strip	Rhoplex <sup>e</sup> (%)	Rhoplex (lbs)	Dow <sup>f</sup> Antifoam B	CaCl <sub>2</sub> (lbs)	Aggregate Moisture Content	Act. Water Added (lbs)	Total Water <sup>g</sup> Per Batch (lbs)	Actual w/c	Batch Volume (cu.ft.)
1	None	None	None	None	8.3%	-	-	-	-
2	None	None	None	None	9.0%	-	-	-	-
3	None	None	None	None	7.0%	3.5	15.25	.44	1.81
4	None	None	None	1.76	8.1%	2.5	14.25	.47	1.93
5	None	None	None	1.76	20%	0.0	13.22	.57	1.93
6	None	None	None	1.76	12.9%	5.5	18.72	.52	2.27
7	None	None	None	None	6.0%	8	21.22	.43	1.76
8	None	None	None	None	5.8%	9	22.22	.47	1.80
9	None	None	None	1.76	7.0%	5	16.75	.45	1.72
10	32	18.75	.43	None	6.0%	8	17.94	.43	1.58
11	None	None	None	None	5.2%	10	21.75	.51	1.87
12	None	None	None	None	5.2%	5	18.22	.42	1.62
13	None	None	None	None	5.2%	10	21.75	.51	1.87
14	32	18.75	.43	1.76	9.5%	8	17.94	.46	1.73

e. Liquid Rhoplex, by weight of cement

f. Antifoam B is 2.29% of Rhoplex MC-76, by weight

g. The total amount of water added = (water from latex/acrylic) + (extra water)

water-cement ratio batch after batch. For that reason water was added until a desirable consistency of the mix was obtained. The desirable consistency was determined by visual inspection and hand manipulation of the mortar. The amount of water added was recorded. This, coupled with periodic estimation of the aggregate moisture content, made it possible to estimate the water-cement ratios actually being obtained.

Fourth, originally the mixes to be broomed were designed with the same sand-cement ratio as those to be screeded. However, when the broomed mixes were changed to a slurry-like consistency a more fluid mix was required. This was achieved by reducing the sand-cement ratio of each basic mix by 0.5.

It should be noted here that the "Rhoplex MC-76" was not part of the basic mix designs provided at the start of the project. The acrylic was included in the field work because of its availability and its use could be compared with the latex.

The moisture content of the aggregate was determined in the field by taking a can of known weight and filling the can with aggregate in three layers. Each layer was rodded before the next one was added. Its weight was then noted and compared with the dry rodded weight.

#### Mixing Procedure

All mixing was done in a gas powered, one bag, portable mixer at the job site. The mixing procedure involved the following steps:

1. The required amounts of aggregate and cement were weighed and combined in the mixer.

2. The mixer was started mixing the aggregate and cement into a uniform blend.
3. The latex or acrylic admixture was weighed and added. The antifoam agent had been previously added to the latex or acrylic.
4.  $\text{CaCl}_2$ , dissolved in three pounds of water, was added to the mix, if required.
5. Water was added until proper workability achieved.
6. The batch was then mixed for a minimum of three minutes.
7. Upon completion of the mixing or when it was needed the batch was poured into a buggy to be transported to the work area.

#### CHAPTER 4: DESCRIPTION AND EVALUATION OF APPLICATION TECHNIQUES

As stated in Chapter 2 one of the project goals was the development and evaluation of the application techniques. In this chapter the overlay application procedures are detailed, any problems encountered are discussed and the techniques evaluated. Discussion of the techniques and their interaction with the various mixes is given in Chapter 5.

It should be noted that the equipment used and the conditions under which they were used were very primitive. This was due in part to the small scale of the project which prohibited the use of mechanical equipment. However, the equipment and materials used proved to be effective, if not always efficient. The mixer used for making all mortars was a one bag, gas powered, portable mixer (Figure 7). This mixer easily handled the approximately 1.75 cubic foot batches used throughout the field work. It mixed efficiently leaving few clumps of dry material.

The platform balance used had a maximum capacity of 160 pounds measuring to a hundredth of a pound. The balance was never loaded to near its capacity and was frequently zeroed.

Prior to laying each strip the pavement receiving the overlay was swept, thoroughly wetted and then swept again. This cleaned the pavement very well. Except for strips 11 and 13 the pavement was always wet when the mortar was placed.



Figure 7. Mortar Mixer

The overlays applied to wetted pavement had much higher workability than those applied to dry pavement. The two strips applied to dry pavement had to have extra water added in order to achieve the proper workability and account for the water lost to the dry pavement. It is also felt the wetted pavement aids in the curing of the overlay by retarding the evaporation of water.

Having the pavement dry prior to receiving the overlay may be advantageous. When the pavement is dry it will suck the water and latex from the mortar into the dry concrete. This may increase the adhesion between the overlay and original pavement.

All joints and cracks were cleaned of loose dirt, bituminous material and concrete. Deteriorated joints or cracks patched with bituminous asphalt were not altered except to remove loose material. A badly deteriorated crack, prior to cleaning, is shown in Figure 8.

Upon completing the placement of a batch, that batch may or may not have been sprayed with curing compound. The curing compound used was Cure & Seal produced by Symons Manufacturing Company. Curing is discussed later.

### Screeding

The screeding procedure was used on strips 1, 3, 4, 5 and 6. After the pavement was "cleaned" the screeding technique involved the following steps:

1. The 3/8" x 1-3/8" door-stop molding was placed on the pavement forming a three foot wide strip, Figure 9.
2. The mortar was dumped into several piles within the strip from a buggy.



Figure 8. Deteriorated Crack in County Road 500N



3. While spreading the mortar to its approximate depth the mortar was brushed into the wetted pavement with a stiff broom. This was done in an attempt to improve bonding, Figure 10.
4. The mortar was now screeded using an aluminum channel, Figure 11.
5. While a batch was being screeded periodic stops were made to patch any irregularities in the fresh overlay. This was usually done with a trowel, but if the problem area was large the overlay was re-screeded.
6. After a batch was placed curing compound was sprayed on the strip if necessary. Curing compound was used only on days when high water evaporation could occur. Therefore it was used on sunny days or warm, windy days. If curing compound was used it was sprayed approximately one hour after placement of the batch. When the compound was not used it was felt the skin formed by the latex was enough to prevent excess evaporation. See Figure 12.
7. The forms were removed anytime after the screeding was finished and before the mortar set.

The largest drawback of the screeding operation was the rate of overlay placement. It took thirty man hours to complete a strip. Since the screeding was done by hand it proved to be very physical making it difficult to complete a strip in one day. Both problems could be partly alleviated by installing a vibrator on the channel. This would cause the mortar to flow into place reducing the amount of physical work while increasing production.

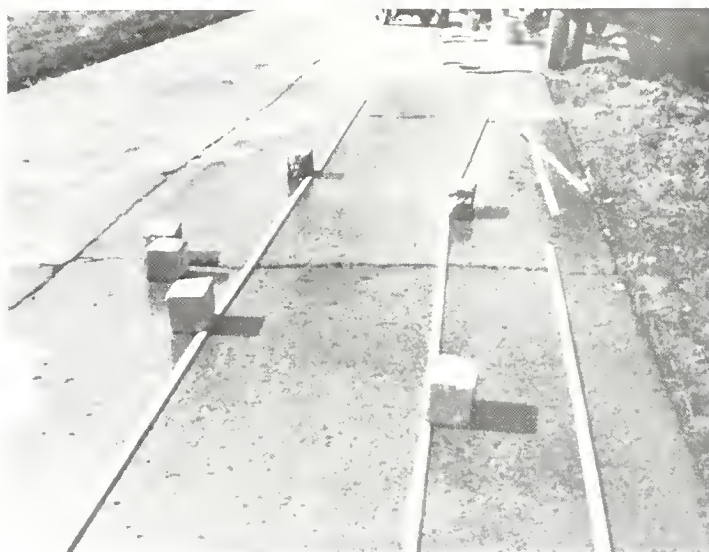


Figure 9. Strip Forms



Figure 10. Brushing Mortar Into Pavement



Figure 11. Screeding



Figure 12. Spraying Curing Compound

A very serious problem with this technique is that of finishing. This was caused by the latex, not the application procedure. Seconds after a batch is exposed to the air the latex forms a thin film all over the surface. This film is easily broken by vigorously working the mortar as in brooming or screeding. However, when tining, the final texturing, was attempted this surface was not broken and the mortar tended to tear. This made tining impractical and was therefore discontinued. The texture produced by the screeding as seen in Figure 13 was thought to have good skid resistant qualities and was used as the final texture.

Another problem with the screeding application technique was that of spreading the mortar to approximately the required depth. If this was not done properly large amounts of mortar would build up in front of the channel making screeding by hand virtually impossible.

The principle advantage of screeding arises in the anticipated life of the overlay. Because of its thickness the overlay should last for many years under normal traffic conditions.

#### Brooming

The brooming technique was used on strips 2 and 7 through 14. Strip 2 was part of Part One and was  $3/8$  inches thick while the other strips were less than  $1/4$  inch. After the pavement was swept clean the brooming method involved the following steps:

1. Form molding was placed on one side of the strip three feet from the edge of the adjacent strip, the forms were used only to mark the proper strip width.



Figure 13. Texture of Screeded Overlay



2. The mortar was dumped into several piles within the strip from a buggy.
3. The mortar was spread out over the strip to its approximate depth. As the mortar was being spread, it was simultaneously being scrubbed into the pavement surface with a stiff broom, Figure 14.
4. After being spread the mortar was then dragged longitudinally by a stiff broom pulling excess mortar forward. Varying amounts of pressure were applied on the broom as it was being dragged. This depended on how deep the mortar was and how harsh the material was. For a given area covered by one broom width from 1 to 4 passes were normally made to obtain the desired thickness, Figure 15.
5. The overlay was then patted with a second broom for purposes of forcing any loose aggregate into the overlay, Figure 16.
6. The batch was then cured immediately after placement by use of a hand sprayer, Figure 12.
7. The forms were removed at a convenient time after the brooming of a batch was finished but before the mortar set.
8. After the mortar had set water was sprinkled onto the overlay in an effort to keep the strip from drying. This was done two to four times for each fresh strip.

The use of the brooming application technique has three major advantages. First, the ease and rate at which the overlay was applied. To complete a strip using the brooming method it took a crew of five about 1.5 hours, or 7.5 manhours. This would allow a crew with the



Figure 14. Spreading Mortar





Figure 15. Brooming Mortar to Desired Thickness



Figure 16. Patting Broomed Overlay

proper experience and equipment to overlay a large area in each working day. Second, because of the overlay thickness, less than 1/4 inch, the yield per batch is very high. Third, no finishing was required because the brooming produces a naturally harsh surface, Figure 17.

The primary disadvantages were obtaining a uniform thickness and curing. When the broom was dragged forward removing all the excess mortar the depth obtained fluctuated depending on the material harshness and pressure applied on the broom. Because the overlay was so thin these fluctuations were very difficult to see. However, with the overlay being so thin variations in the depth of  $\pm 1/8$  inch or more are almost undetectable when driving. The real problem of the overlay being broomed so thin lies in intended overlay life being significantly reduced.

On hot, sunny days the overlays tended to dry very quickly if they were not cured with curing compound shortly after being placed. Even prompt curing was not enough to prevent detrimental water evaporation on the hottest days. Under these circumstances water had to be sprinkled over the overlay to prevent excessive evaporation.

When comparing the two application techniques brooming is definitely more efficient to use, it was four times faster to place a strip than with the screeding technique. On the other hand the screeded overlays will have a life much greater than that of the broomed overlays. This is not only because of the thickness but because it is anticipated that the individual aggregates particles will become dislodged from the broomed overlays. With the screeding



Figure 17. Texture of Broomed Overlay

technique each aggregate particle is forced into the mortar by the action of the channel. But with the brooming method the particles tend to sit on top of the mortar with more of each particle exposed. This makes it more susceptible to being broken away from the mortar.

Generally, the brooming technique would be easier used in actual field use because of its fast application rate. Once a local area of low skid resistance (a curve or intersection) was discovered and found necessary to improve, the area could feasibly be repaired between the morning and afternoon peak traffic hours. This would minimize traffic delays and driver inconvenience.

## CHAPTER 5: EVALUATION OF OVERLAYS

This chapter deals with the evaluation of overlays with respect to the mixes and their placement, adhesion, skid resistance and a plan for future evaluation of the overlays.

The section discussing the mixes and their placement deals with the interaction between them and how it affected the overlay as a whole. The overlay bonding is evaluated by visual inspection and soundness tests over time. The skid resistance was measured by a skid trailer. The skid resistance will be periodically monitored for changes in the skid number.

The plan for future evaluation of the overlays continues for another year. This will allow the overlays to have been exposed to a full year of weather cycles as well as traffic.

### Mix and Placement Interactions

The most prevalent interaction was that of aggregate separating from the mortar when it was being placed. Regardless of the mix or application technique, segregation always occurred when using the lightweight aggregate. During the screeding operation, as the channel was being moved across the strip, substantial amounts of the larger particles would separate from the mortar that was adjacent to the channel. If these particles were not removed or forced back into the mortar they would pass under the channel leaving areas of

lightweight aggregate particles with an insufficient amount of mortar to secure them.

In the brooming process as the mortar was being dragged forward, as described earlier, the larger lightweight aggregate particles would separate. Therefore, as the brooming continued the amount of paste in the mortar decreased until at the end of a batch, or part thereof, the last 6 to 12 inches of the strip was aggregate without mortar. This problem could be partially rectified as the brooming progressed by frequently remixing the segregated aggregate with the mortar.

It should be noted that the segregation problem of the lightweight aggregate was always more severe with the larger sand-cement ratio.

There were only minor segregation problems with the slag which did not cause difficulties.

The second noted interaction was that for a given mix of either slag or lightweight aggregate screeding technique worked better than brooming technique. In the case of the lightweight aggregate the screeding technique caused less segregation of the mortar than did brooming. Because of the reduced segregation the mortar in the overlay was more uniform throughout a batch and was easier to work with. To a lesser degree the same is true for the slag.

The third interaction was that for a given application technique and aggregate the mix with the lowest sand-cement ratio was the most workable. This was as expected because there is more paste available per unit of aggregate with the lower sand-cement ratio.



It was also observed that with the overlays placed on dry pavement (strips 11 and 13), the mix had to be more workable in order to be broomed as effectively as when broomed on wet pavements.

The use of the acrylic admixture in lieu of the latex admixture made no difference in the placement of the mixes. However, because the proper anti-foam agent was not used in the acrylic numerous small bubbles appeared throughout the entire surface of the overlay.

#### Adhesion

At the time of this writing there had been no bonding failures due to lack of adhesion. There were two failures noted in the screeded overlays but these were caused by expansion of the underlying pavement. In both cases the area of failure was located directly above a large bituminous patch. When the original pavement expanded on the hot days that the failures occurred it expanded towards the patch. This caused the overlay to buckle as the compressive force was applied. Figure 18 clearly illustrates the buckled overlay. This can easily be eliminated by simply putting a joint at such a location. This failure did not occur in the broomed overlays.

A simple soundness test was used to check for sound bonding. This test involved tapping the overlay with a hammer. If a hollow sound was heard there was no bond between the overlay and pavement. This test was only applied to the screeded overlays because the broomed overlays were too thin for the test to be effective. When testing the adhesion it was found that wherever the screeded overlay was placed over bituminous material there was no bond. This was anticipated. In





Figure 18. Buckling of Strip Number 6

actual large scale use of the screeding method all bituminous material would have to be removed in order to get good bonding.

It should be pointed out here that the overlays laid in Part One failed in bonding, due to lack of adhesion, in just one week. The Part One overlays did not have either acrylic or latex admixture in the mixes to improve adhesion. The photographs in Figure 19 illustrate the adhesion problems encountered with the overlays placed in Part One of the field work. The bond between the overlay and pavement was weak enough to allow the overlays to be removed by hand with very little force applied.

With regards to the broomed overlays it is not anticipated that there will be bonding failure as in the thicker overlays. Here it is felt failure will most probably occur not when large pieces of overlay break loose but when the individual aggregate particles are removed from the overlay prematurely by tire action. A good indication that this will not happen was given through the skid testing. After the skid trailer had passed over the broomed overlays with the wheel locked there was no visible damage to the overlay indicating that there was good bonding of the aggregate particles to the overlay. It is possible for the broomed overlays to fail as the screeded one will but this is less likely than the just discussed type of failure. If the overlay did fail because of lack of adhesion between the pavement and overlay it will be of little consequences other than lowering its skid resistance. This is because the overlay would peel off the pavement like paint and be of little danger to passing vehicles.



Figure 19. Adhesion Problems of Part One

Evaluation of bonding points out a major advantage of the brooming application technique. When bonding failure occurs in the screeded overlays several problems occur. First, the riding quality of the roadway is greatly reduced. Second, tire noise increases and third, there is a chance that a piece of overlay large enough to break a windshield could be thrown into the air by a tire. None of this occurs with the broomed overlays.

The evaluation of adhesion will be made through a continuous process involving frequent visual inspections and soundness tests. A critical period for the overlays will be winter when there are severe freeze-thaw cycles to endure. By the end of the first winter more than 90% of each Part One strip had failed in bonding.

#### Skid Resistance

The most important overlay evaluation criteria is that of skid resistance. Skid resistance is measured by means of a skid trailer being towed across the pavement with one wheel locked according to ASTM E 274. After the skid tests are taken the skid number of the pavement is found. The skid number is the measure of the pavements skid resistant characteristics and are relative to each other. A skid number of 30 is considered poor while a number in the mid-fifties is good.

It was originally planned to obtain skid numbers for each strip at 40, 50 and 60 mph. However, due to the roughness of the approach areas to the strips this was not possible without damaging the skid testing equipment at the 50 and 60 mph speeds. Therefore, skid

numbers were obtained only for the 40 mph speed. These numbers are shown in Table 8.

For each strip three skid numbers were developed except for strip 6 which had only two, and the average of the three numbers represents the skid number in Table 8. All readings were taken from the same portion of each strip. The skid tests were taken four days after completion of the project.

Figures 20 through 25 are examples of the surface textures achieved. Figures 20 and 21 show the surface textures of the screeded overlays while Figures 22-25 are broomed overlay.

Upon close examination of the skid numbers, the following conclusions can be drawn:

1. The broomed overlays have considerably higher skid numbers than the screeded overlays.
2. With the lightweight aggregate used in brooming, as the sand-cement ratio decreases the skid number increases.
3. When using slag in brooming, as the sand-cement ratio increases the skid number increases.
4. The primary factor influencing skid resistance is the application techniques.
5. Strips 10 and 14 used acrylic admixture while their counterparts, strips 12 and 8 respectively, used latex admixture. There are no differences in the effect the admixtures have on skid numbers.

Table 8. Skid Numbers

Overlay Number	Skid Number	S.D.**	Speed	Overlay Technique	Aggregate
1*	40.6	-	41.5	screed	natural sand
2*	43.2	2.66	39.5	broom	natural sand
3	38.2	2.57	40.0	screed	slag
4	34.2	3.78	40.1	screed	slag
5	39.4	3.46	40.1	screed	lightweight
6	40.8	-	40.2	screed	lightweight
7	72.8	2.06	39.9	broom	lightweight
8	61.8	1.32	40.0	broom	lightweight
9	50.9	2.10	39.4	broom	slag
10	49.1	1.66	39.6	broom	slag
11	72.6	2.27	40.0	broom	slag
12	59.0	1.71	39.3	broom	slag
13	62.8	3.40	40.1	broom	slag
14	65.2	1.96	39.2	broom	lightweight

\*Part One data recorded one week upon completion of overlay number 2.

\*\*S.D. = standard deviation.



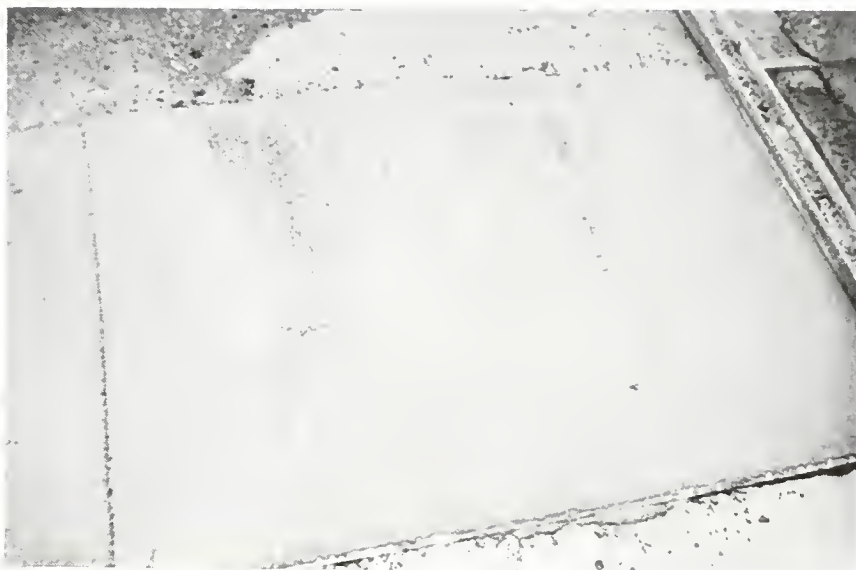


Figure 20. Surface Texture of Screeded Overlay, Strip 3



Figure 21. Surface Texture of Screeded Overlay, Strip 6



Figure 22. Surface Texture of Broomed Overlay, Strip 9



Figure 23. Surface Texture of Broomed Overlay, Strip 10



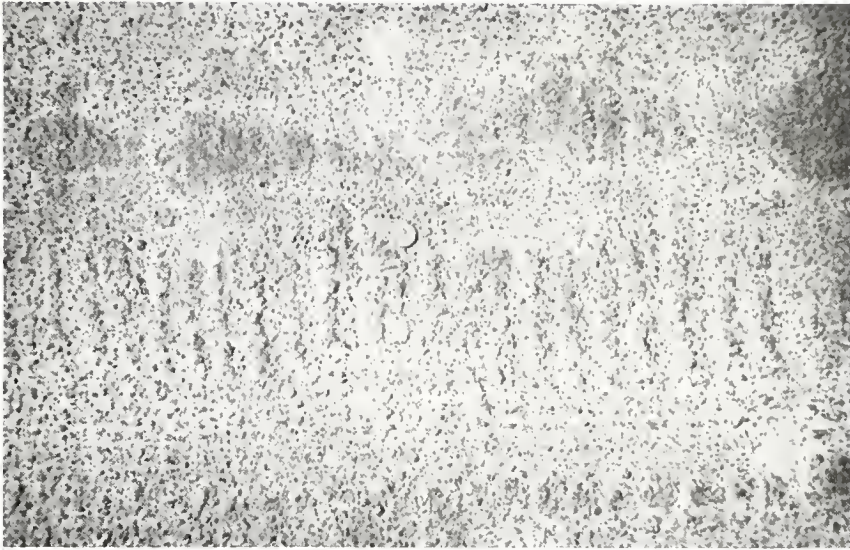


Figure 24. Surface Texture of Broomed Overlay, Strip 12



Figure 25. Surface Texture of Broomed Overlay, Strip 13

A few comments concerning the skid numbers should be made. First, the reason for strip 4 being of such low skid resistance is because plastic was used to cover the strip during a rainfall. This plastic causes the surface to become very smooth.

Second, there is no explanation as to why strip 11 produced such a high skid number. This is much higher than the rest of the broomed overlays with slag.

Third, when the skid tests were taken after completion of Part One the skid trailer pulled up large pieces of overlay as it was towed with the wheel locked. This did not occur in Part Two.

#### Plan for Future Evaluation

As stated earlier the evaluation of the twelve strips will be a continuing effort. The plan for further evaluation is a very general one. There are two main parts to the plan. Part One will be concerned with evaluating the overlay bonding through visual inspection and soundness test. Periodic visits can be made to the job site for this purpose. Any unsound areas can be noted and then compared with the type of mix used at that location.

Part II will deal with taking monthly skid tests and comparing the new skid numbers to the previous one. This will detect which mixes produce the best skid resistance. Taken into account here must be the fact that strips 7, 8, 11 and 12 are in the center of the south bound lane and therefore not susceptible to as much traffic wear. But because the traffic volumes are extremely low this may have little effect.

This evaluation should be carried out for a full year. This will allow the strips to endure a full year's cycle of weather. At the end of one year enough data should be available to try one or more mixes on a larger scale under normal traffic volumes.

## CHAPTER 6: PRACTICAL FIELD USE OF APPLICATION TECHNIQUES

It should be reiterated that the equipment and procedures used in this research project were very crude. However given the proper equipment and expertise it is felt both the screeding and brooming techniques could be used on large scale resurfacing jobs. Each method has its own advantages and disadvantages that must be viewed in the light of a particular situation.

Briefly, the advantages and disadvantages of both methods are as follows:

### Screeding:

#### Advantages:

1. Longer life relative to brooming assuming there is continued adhesion.
2. Smoother ride than with brooming.
3. Ease of curing.

#### Disadvantages:

1. Slow rate of placement
2. Difficulty in finishing
3. Rough ride, noise and hazards related to failure of adhesion.
4. More difficult to apply than brooming.

### Brooming:

#### Advantages:

1. Fast and easy to apply.
2. Very high initial skid numbers.
3. Requires less materials.
4. No finishing required.
5. No danger, noise or rough ride from overlay adhesion failure.

#### Disadvantages:

1. Short life span relative to screeding.
2. Difficult to obtain a uniform thickness.
3. Very difficult to cure.

### Practical Field Uses

Keeping these advantages and disadvantages in mind a few possible field uses can be formulated. On heavily travelled expressways or arterials the brooming technique could be used on dangerously slick curves or at intersection approaches as an interim solution to low skid resistance until a more permanent solution is feasible. The overlay could be applied between the morning and afternoon rush hours thereby minimizing disruption to traffic or during the night which would reduce the curing problem.

On lesser travelled highways and intersections the brooming technique could be used as a more permanent solution to skid resistance problems.

The screeding overlays could be used as a permanent high quality, skid resistant surface regardless of the traffic volumes. This overlay would be far thinner than other high quality, skid resistant surface, which run from 1-1/4 inches to 2 or more inches. Therefore very high quality aggregates and admixtures could be used that would otherwise be too expensive to use in the thicker overlays. Also, because the screeding overlay is so thin the placement rate would be faster than that of the thicker overlay given the proper equipment.

#### Expansion of Research Techniques to Field Use

There would be few problems in expanding the brooming technique to actual field use. The size of the operation, that is number of men required and equipment size, would be dependent on the size of job to be done. An intersection approach, say 12 feet wide and 300 feet long, could be finished in approximately ten working hours using five labors and a one bag mortar mixer. With a larger mixer and two more labors the time could be halved. On larger jobs with adequate manpower a ready mix truck could be used efficiently to supply the mortar or a "concrete mobile" might be used.

The adaptation of the screeding method to a larger scale presents only one major foreseeable problem. That is mechanizing the screeding operation as much as possible. Ideally the screed could be equipped with its own drive system and vibrating system. This would greatly reduce the amount of time and physical work required to screed relative to the research method. It is difficult to estimate the amount of time saved by such mechanization. A reasonable estimate would be 40 to 70 percent.

Two problems that would have to be examined closely are curing and mix size. As stated earlier curing of the broomed overlay is difficult. A solution to the curing would be to use a sprinkling system to keep the overlay wet. The mix size can be very deceiving. If the mix is too large some will be wasted because it will set before it is placed. With the use of accelerators this problem is even more severe. A very important consideration in determining mix size is weather. On hot, sunny days the mix size must be smaller because of faster set times.

Another difficult problem to be investigated is that of pavement cleaning. Since these overlays can be placed directly on the original pavement surface non-destructive cleaning methods can be used. Water-blasting is a very effective cleaning technique and is less polluting than sandblasting.

Also to be considered is the repair of faulty cracks or joints. All structurally unsound joints or cracks should be replaced. Any areas of D-cracking should be removed as should all bituminous materials.



## CHAPTER 7: SUMMARY, FINDINGS AND CONCLUSIONS

### Summary

Initially the project was broken into two parts. Part One dealt with the work done in the Fall of 1977. This work had no bearing on the project other than to gain experience from it. Upon completion of Part One several changes were made in Part Two.

Part Two was the work done in Spring 1978. Initially three application techniques were to be used: brooming, screeding and shotcrete. But due to circumstances beyond the author's control shotcrete had to be dropped.

The mixes were provided by Mr. Jorge Gomez. The mixes involving brooming were altered so that the sand-cement ratio was reduced by 0.5. This made the mixes more slurry-like allowing them to be spread in a thinner section.

Twelve strips, each 3 feet wide by 150 feet long, were placed. The first four were screeding and the rest were brooming. Of the screeded overlays two used lightweight aggregate, the other two were slag. All four used latex as the admixture. Three of the eight broomed overlays contained lightweight aggregate one of which used acrylic "Rhoplex MC-76" in place of the "Latex 464". One of the slag, broomed overlays also used the acrylic admixture.

Of the aggregates involved the slag was easier to use because the lightweight aggregate separated from the mortar when used.



Of the application techniques brooming was much easier to use and was four times faster than the screeding method.

Brooming provided the highest skid numbers while strip #7 had the highest individual skid number.

Each application technique has a practical use in the field and can possibly be expanded to fit the larger scale jobs.

### Findings

1. A select mix proportion can be taken from laboratory work and applied as a thin surfacing for improvement of skid resistance on concrete pavements.
2. Brooming and screeding are both effective methods to apply very thin overlays.
3. A wide range of mixes can be applied as thin surface applications on concrete pavements.
4. Brooming was four times more efficient than screeding with respect to man-hours per strip.
5. The broomed overlays provide the highest skid resistance.
6. The screeded overlays need surface texturing in order to increase the skid numbers into the "good" range.
7. Of the two aggregates used the lightweight aggregate provided the best skid resistance.
8. Strip #7, mix #7 provided the highest skid resistance.
9. The primary factor that influenced the skid resistance of an overlay was the type of application technique.
10. Good workability was achieved by all mixes placed in the field.

11. Both slag and lightweight aggregate developed satisfactory skid resistance when used in overlays.
12. There was no significant difference between using the acrylic and latex with respect to workability and skid resistance.
13. The application techniques can be successfully expanded to larger scale practical field use.
14. Approximate yields for the brooming technique are as follows:
  - a. One cubic yard of mortar will cover 155 square yards of pavement.
  - b. 100 pounds of latex will cover 40 square yards of pavement.
15. Approximate yields for the screeding technique are as follows:
  - a. One cubic yard of mortar will cover 68 square yards of pavement.
  - b. 100 pounds of latex will cover 21.3 square yards of pavement.
16. The following factors were not considered in the experiments:
  - a. experience of the crew.
  - b. weather.
  - c. deteriorated condition of the pavement joints and cracks.

### Conclusions

1. Brooming worked well because it was fast and easy to apply, yielded high skid resistance and was the least expensive with respect to material costs.

2. Screeding yields skid numbers which were lower than those from brooming. This is obviously due to surface texturing not being used on the overlays because it was not feasible.

## CHAPTER 8: RECOMMENDATIONS FOR FUTURE WORK

1. Continued monitoring of the overlays on a regular basis.
2. The use of shotcreting as a possible application technique for overlays 3/8 inch thick and thinner.
3. The use of promising application techniques and mixes in larger scale practical field work under heavier traffic conditions.
4. When used on larger scale clean all bituminous material off the pavement and repair deteriorated cracks and joints.
5. Use waterblasting to clean the pavement.
6. Develop surface texturing for screeded overlays to improve skid resistance.

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